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PRESENTATION ON
DEU ammunition storage in earth covered ISO-Containers

Dipl.-Ing. Michael Steyerer, Dipl.-Ing. Oliver Stange

Bundeswehr Technical Center for Protective and Special Technologies (WTD 52)
83458 Schneizlreuth, Germany
Tel.: +49–(0)8651–791379 (Fax: 1600); email: MichaelSteyerer@bwb.org ; Oliver1Stange@bwb.org

ABSTRACT

The German military has currently requested an earth covered storage solution for ammunition and explosive using ISO-containers. The development of the solution was conducted by the WTD 52.

In Germany, the WTD 52 is the central provider for military requesters with respect to questions associated with the safe storage of ammunition in missions abroad. During the last few years, many test campaigns have been conducted/managed by the WTD 52 and led to useful and certified storage solutions which were presented at DDESB 2008.

For testing purposes, corresponding structures of ISO-Containers in scales 1:1 and 1:2 were created. The test setup differs not only with respect to the scaling, but also with regard to earth cover and distance between adjacent ISO-Containers. Additionally, barricades are applied in the primary blast direction. The experiments were performed with different types of ammunition. Besides the general visual damage inspection, video recording, pressure measurements and debris collection were used for the evaluation. The tests will lead to a certified storage solution for ammunition in earth-covered ISO-container

The test results/final products will be directly incorporated into the “Handbook for the Physical Protection for Ammunition Storage in Operations”, which was published by the German Armed Forces Office - Division V Infrastructure and presented at DDESB 2008.

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14. ABSTRACT
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15. SUBJECT TERMS

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Study Objective:

One objective of the study is to verify the necessary/suitable depth of earth cover and distances between the individual potential explosion sites (PES) in order to reduce the hazard posed by blast and debris dispersion and to avoid a sympathetic detonation. Another is to keep the extent of damage caused to adjacent storage facilities within acceptable limits.

Background

During operations, ammunition is generally stored in ISO or wooden containers positioned at some distance from the camp proper in areas separated by barricades. This keeps the hazard and extent of damage to human and material assets within acceptable limits in the event of an undesired incident involving ammunition.

Storage in ISO container

Storage in a wooden ammunition container

Figure 1: Storage of ammunition during operations

Due to the fact that relatively large quantities of ammunition may have to be stored, the residual risk is significant and can only be controlled by maintaining large quantity distances. However, this results in a lot of space being required.
With regard to the use and design of an earth-covered storage facility for subclass 1.1 ammunition, the variant of an earth-reinforced ISO container appears to be the best solution.
The tests performed under Military Requirement 223 have shown that earth-covered ISO containers including hollow steel profile reinforced wall and roof surfaces for absorbing the earth pressure are a technically and economically suitable solution for storing ammunition during operations [1+2].

Background / Previous Study Results

⇒ Reduction of pressure in the rear earth-covered area

⇒ Focus of pressure propagation in the front area

⇒ Reduction of debris load in the rear earth-covered area

⇒ Directed distribution of debris in the front area

⇒ Reduction of secondary debris load when the right infill material is selected for the earth cover

⇒ Reduction of secondary debris load when a suitable construction system is chosen

Figure 2: Previous study results

Additional studies are required to verify the findings gained so far and to attain an operational solution. It would particularly make sense to conduct further studies in order to be able to determine the quantity distances required for the different quantities of ammunition stored. In addition, an ultimately certified system provides an alternative to the current physical protection measures that can be taken for storing subclass 1.1 ammunition.

Test Planning

The system will be put through extensive tests and finally certified for use in an experimental demolition campaign at the Reiteralpe Proving Ground of Bundeswehr Technical Centre (WTD) 52 and at the test site of Bundeswehr Technical Centre (WTD) 91.

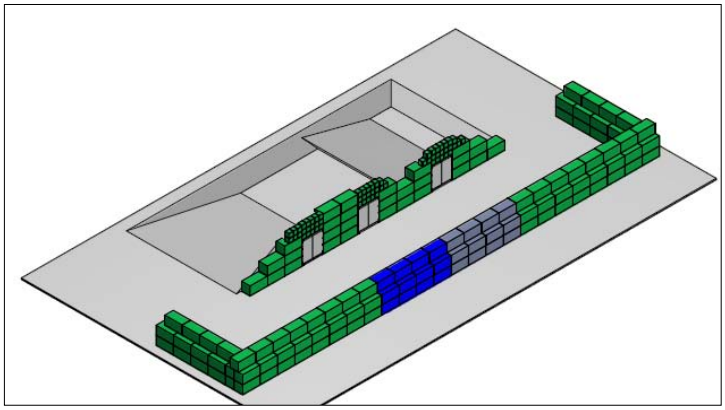


Figure 1: Basic idea

The objective is to:

- determine the debris distribution/characteristics produced by detonation inside an earth-reinforced/earth-covered ISO container,
- reduce secondary debris by using a suitable storage facility,
- reduce secondary debris by selecting the right earth cover material,
- determine the external air blast attenuation provided by a detonation inside an earth-reinforced/earth-covered ISO container,
- reduce field distances
- check two design options (A, B),mix1:2 and 1:1 scale tests,
- use bare charges and ammunition (155mm shells)
- get WTD 52 and WTD 91 to work jointly.

The test is in principle designed to allow a basic distance from the previous tests [2] to be used as a foundation, though distance A can be increased or decreased by X1 or X2, depending on the results of the previous tests[2]. As regards the distances between the containers, account is also taken of the quantity distances currently recommended in German and international regulations, notably AASTP 5.
The depth of the earth cover will vary *(Table 1)* to allow the effects of different depths of earth cover to be examined when certain charge quantities are used.

The tests will be conducted as a mix composed of real tests (M 1:1) and scale tests (M 1:2). The test series will be concluded in 2011 with a range of dynamic penetration trials (120 mm mortars) to examine and verify overhead protection (OHP).

Test No.	Scale	Charge density [kg/m³]	Charge quantity [kg]	Variant	Distance A [m]	[1]X1 [m]	X2 [m]	H [m]	Site
V_1	1:2	5.6	25	A					WTD 52
V_1R[2]	1:2	5.6	25	A					WTD 52
V_2	1:2	11.1	50	A					WTD 52
V_2R	1:2	11.1	50	A					WTD 52
V_2S[3]	1:1	11.1	400	B					WTD 91
V_3	1:2	16.8	75	A					WTD 91
V_3R	1:2	16.8	75	A					WTD 91
V_3S	1:1	16.8	600	B					WTD 91
V_4	1:2	22.3	100	A					WTD 91
V_4R	1:2	22.3	100	A					WTD 91
V_5	1:2	27.9	125	A					WTD 91
V_5R	1:2	27.9	125	A					WTD 91
V_5S	1:2	27.9	125	B					WTD 91
V_6	1:1	Mortar	120 mm	B					WTD 91

Table 1: Test Planning

Variants A and B *(Figures 1 and 2)* differ in the design of the earth cover.

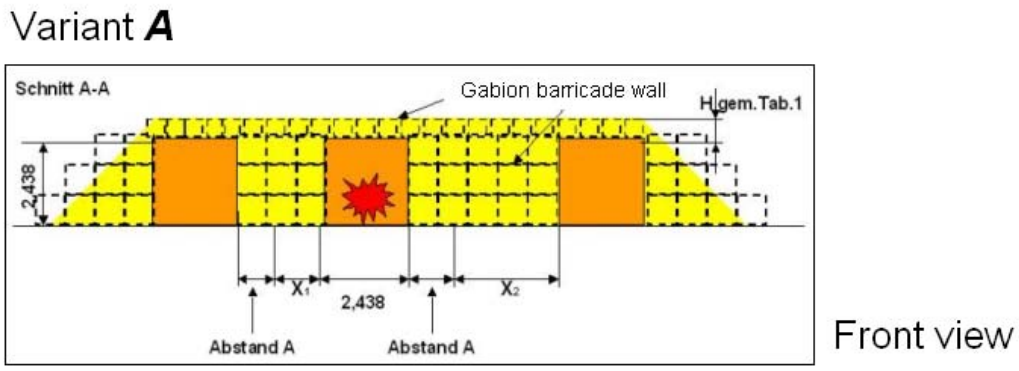


Figure 1: Variant A

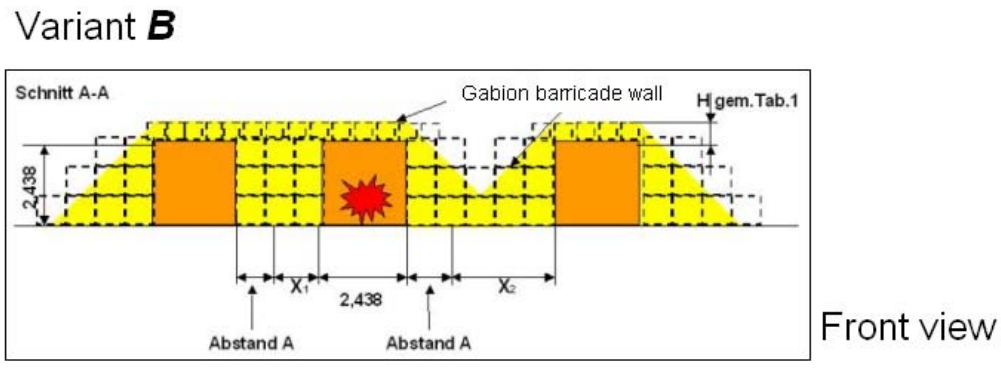


Figure 2: Variant B

[1] The distances X1 and X2 are reference distances and can be altered, depending on test results
[2] R = reference test; the test parameters should be altered on the basis of the previous test
[3] S = special test; such tests must be conducted as required or due to test results and always build on the previous tests carried out

In the case of Variant A, which can be described as the standard variant, there is a full-length earth mound between the ISO containers.

The barricades in the front area are designed as permanent elements (*Figure 3)*, the criteria for their dimensions being the maximum likely size derived from the test plans and the maximum quantity of ammunition planned to be stored. It is assumed that they will not be damaged or destroyed during the verification process and so can be used for several tests. The middle segment *(Figures 3)* must be replaced after every test.

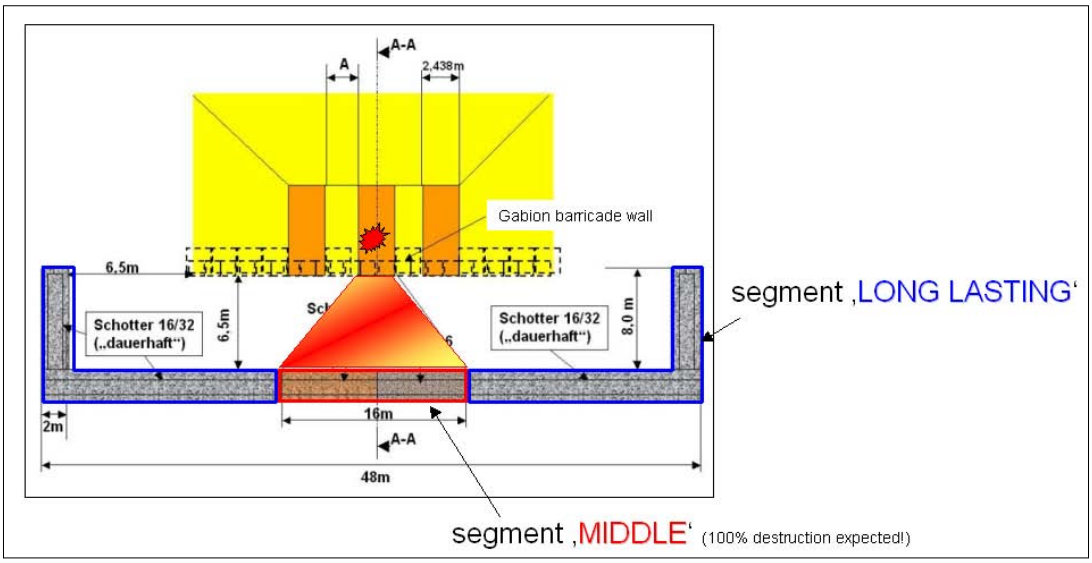


Figure 3: Segment LONG LASTING and segment MIDDLE

This is the segment in which the greatest amount of damage is expected and is not connected to the rest of the mound and so is easy to replace.
Different kinds of material will be used to fill the part of the mound composed of the replaceable segment so as to allow confirmation or verification of the results of the tests conducted to determine the “secondary debris load of barricades”.

The type of barricades system used will a gabion-type system that due to its characteristics will adequately interlock both horizontally and vertically and so be highly resistant to blast. WTD 52 has verified this in several experiments in recent years.

Test Conduct

Several 1:1 and 1:2 scale tests have been conducted in 2009 and 2010. The example described here is a test carried out with 400 kg of explosives.

1:1 Scale:

The type of container used for the tests was a new 20ft container, measuring 8.6ft in height and tested in accordance DIN/ISO 1496 Part 1, conforming in weights and classification to DIN/ISO 668 Series 1, Type CC, with corner fittings as specified in DIN/ISO 1161, a standard steel design with a 28 mm thick plywood floor and standard door.

The walls and roof were reinforced to enable the blasts to be absorbed by the earth cover. The weight of the maximum earth cover was used to determine the size of the earth cover for the ISO containers. Figure 4 show the reinforced ISO containers used for the tests.

Figure 4: Reinforced ISO-Containers

The set-up for the tests was as described earlier, with one donor (the container in the middle) and two acceptors (the containers on the right and left). In accordance with the test matrix, the distances between the containers were in conformity with the distances recommended in German and international regulations and AASTP 5. This allowed a comparison to be drawn between the different regulations.

The following figures show the set-ups for the tests.

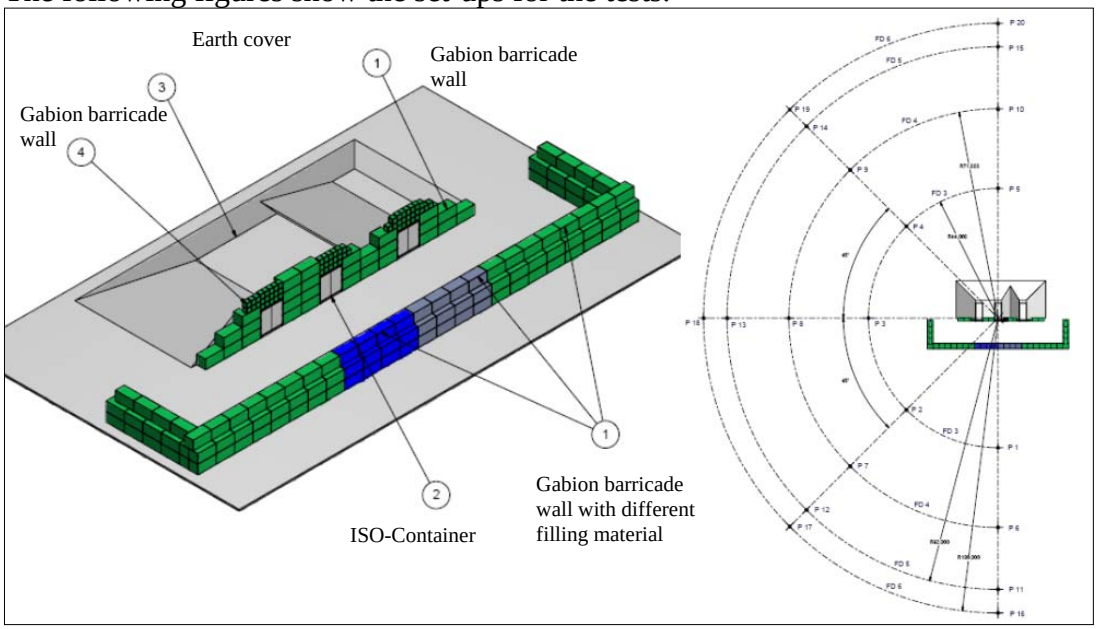


Figure 5: Test set-up

Figure 6: Test set-up

The ammunition used was the 155mm L15A2. The explosives quantity was 11.5 kg per shell. The storage scenario used was the worst-case scenario. The shells were stored upright, in the middle of the middle ammunition container (potential explosion site).

Figure 7: Ammunition – container at the center

There was a pallet with 155 mm UEB DM 108 shells and ammunition crates (dummies) in each of the adjacent containers. They were positioned as shown in Figure 8. Verification plates (1.5 mm galvanized steel plates) were also attached to the sides facing the donor.

Figure 8: Dummies– container to the right

Analysis

Pressure measurement:

The pressure sensors were placed in a semi-circle around the symmetrical test set-up, at the characteristic distances.

The distances were as prescribed for the explosives quantities involved and as recommended in AASTP 5.

- The pressure measurements were filtered and analyzed
- A pressure-time line was drawn (in a graph) , side-on for open area
- Pulses were noted (in a graph)
- The data was entered into an Excel chart (pressure, time of impact, positive duration of pressure, pulse)
- The data was provided as an ASCII file.

Documentation of distribution of fragments and debris

The distribution of fragments and debris was documented. The fragments and debris were measured and catalogued with the aid of coordinate system, with the following data being noted:

- type, size, weight and shape of fragments and debris,
- their distance from the point of impact
- general photo documentation with assignment of images

High-Speed/Video (1000B/S):

The tests were documented by means of high-speed and video recordings, the characteristic image sections being as shown in the following figures and the camera being positioned to determine the velocity and angles at which debris was distributed.

Figure 9: High-Speed-Video

Summary

Over the last few years, Germany has put considerable effort into designing state-of-the-art certified storage facilities for ammunition in camp ammunition storage scenarios. In order to help the responsible officer in the field in selecting and erecting suitable ammunition storage facilities, WTD 52 has worked with its partners to compile all the certified ammunition storage solutions in one comprehensive document, the "Handbook for the Physical Protection for Ammunition Storage during Operations". All the certified technical solutions are systematically categorized in this unique service publication. Detailed illustrated explanations help the user to find the best solution for each storage scenario in the field. The Handbook is a powerful tool in improving safety in ammunition storage in missions around the globe.

The same applies to the integration of the results of the tests described here and the instructions for users of these systems on how to set them up.

Reference Documents

[1] Armed Forces Office (SKA) V 6
Military Requirement No. 238, Ammunition Storage in Earth-Covered ISO Containers
Bonn, September 2007
[2] Steyerer M., WTD 52 – GF 210
Time and cost schedule for "Ammunition Storage in Earth-Covered ISO Containers" Oberjettenberg, November 2007
[3] Steyerer M., WTD 52 – GF 210
Test planning for "Ammunition Storage in Earth-Covered ISO Containers"
Oberjettenberg, October 2008

WTD 52 - Spitzentechnologie
in den bayerischen Alpen

DEU ammunition storage in earth covered ISO containers

Michael Steyerer

Bundeswehr Technical Center for
Protective and Special Technologies

Business Area 210

Bundeswehr

Prepared by

Michael Steyerer
Civil engineer - Structural engineering

WTD 52 – Business Area 210

"Protection of infrastructure against weapons effects and asymmetrical threats, ammunition storage"

Areas of responsibility:

- Safety aspects in the context of ammunition storage on deployment
- Protection against terrorist attacks
  - Study support
  - Test performance
  - Conceptual work

Outline

- Goal of research / project group MF 238
- ‚Roadmap' to solution
- Test plan
- Test conduct 2009
- Summary

Goal of Research

Goal of research

Main goal:

Development of an alternative storage solution for ammunition in the field

→prevent sympathetic detonation of adjacent stacks of stored ammo

→suitable for storage of HD 1.1 ammo

→reduction of field distances (FD)

400 kg TNT equivalent, Meppen 2009

Reference documents: Project 4F020, "Safety of Temporary and Permanent Ammunition Storage Sites"
Military Requirement No. 238 "Ammunition Storage in Earth-Covered ISO Containers"

Project Group MF 238

WTD 52

⇒ **WTD 52 – GF 210**

Management, development, planning, verification trials, overall coordination, assessment

WTD 52 – AF 110 (high-speed/video recordings)

WTD 91

⇒ **WTD 91 – AF 110**

Verification trials / final load tests

WTD 91 – GF 220 (pressure measurements)

WTD 91 – GF 240 (high-speed/video recordings)

SKUKdo

⇒ **Joint Support Command (SKUKdo) NBC Defense and Protection Tasks (Abw SchAufg) III 1**

Point of contact for matters related to ammunition safety

SKA

⇒ **SKA V 6**

Official point of contact of the armed forces (Military Requirement)

Test conception

Test conception

Governing issues:

→ reduce land ‚consumption'

→ reduce costs (much less gabions)

→ increase stability (longevity)

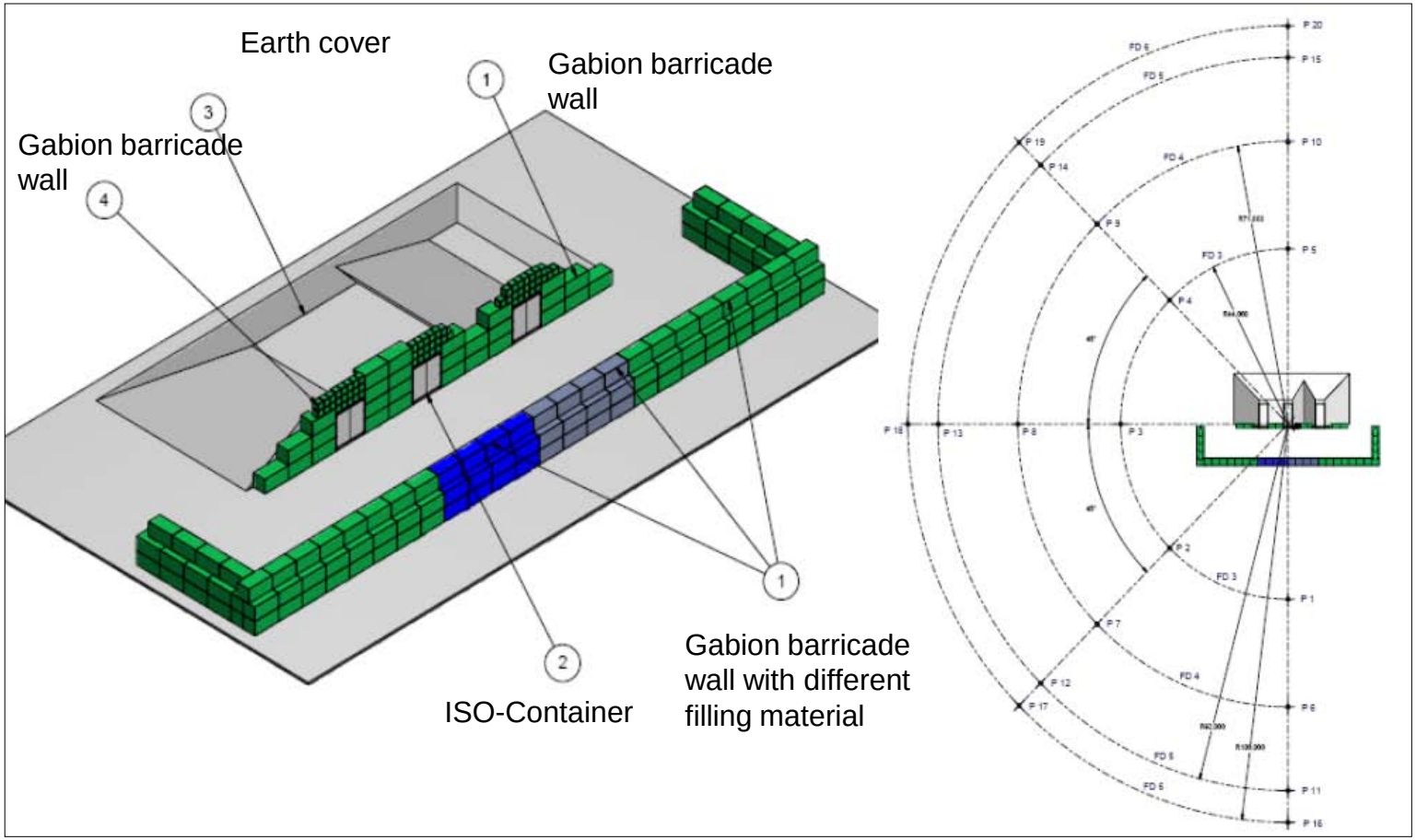
→ reduce field distances (backside, field camp)

→ provide storage temperature reduction (summer!)

→ provide basic protection against top attack

Test conception

Basic idea:



Test plan

Test series specifications

→ check two design options (A, B)

→ mixture of 1:2 and 1:1 scale tests

→ bare charges and ammunition (155mm shells) used

→ joint effort WTD 52 , WTD 91

Workshare

WTD 52

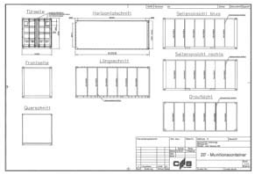
WTD 91

- Development test plan; material needs; pre planning of tests

WTD 52

Bundesamt für Wehrtechnik und Beschaffung

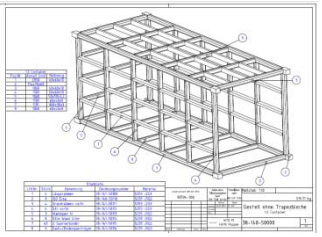
- ISO-container static calculation to accommodate earth pressure load; procurement of ISO containers for 1:1 scale tests

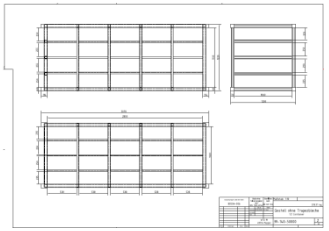


WTD 52

WTD 91

- Dimensioning of earth-covered ISO containers for 1:2 tests (identification of materiel requirements and design drawings)



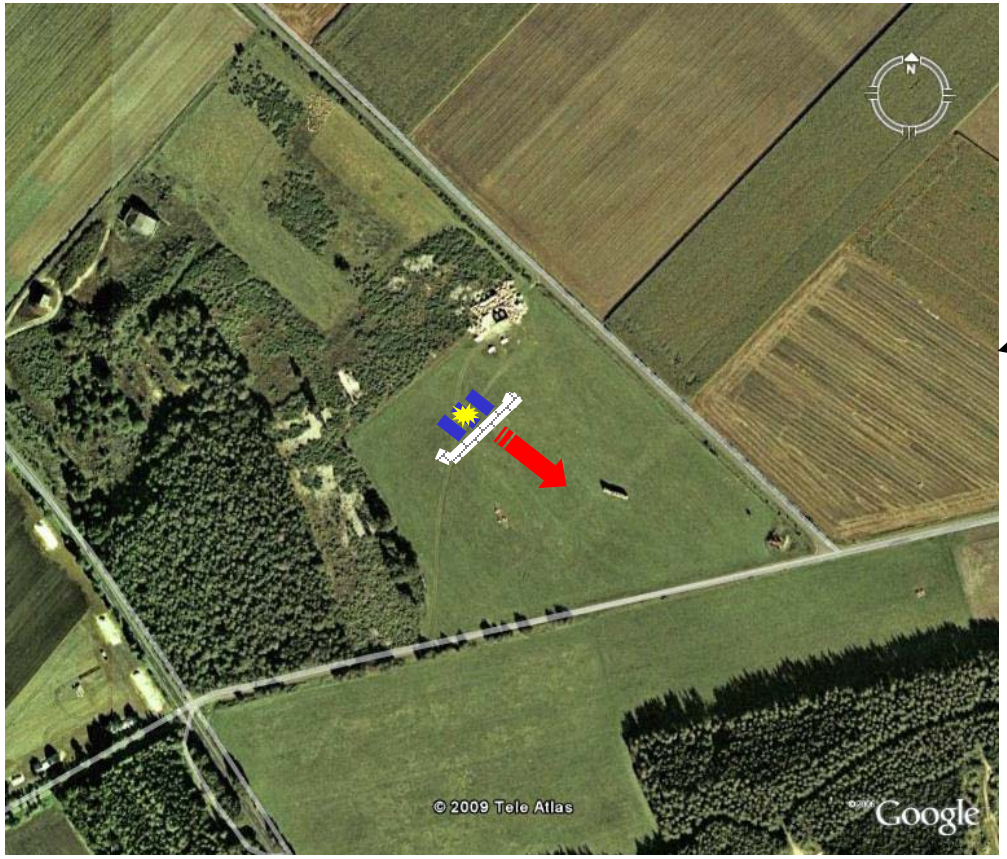


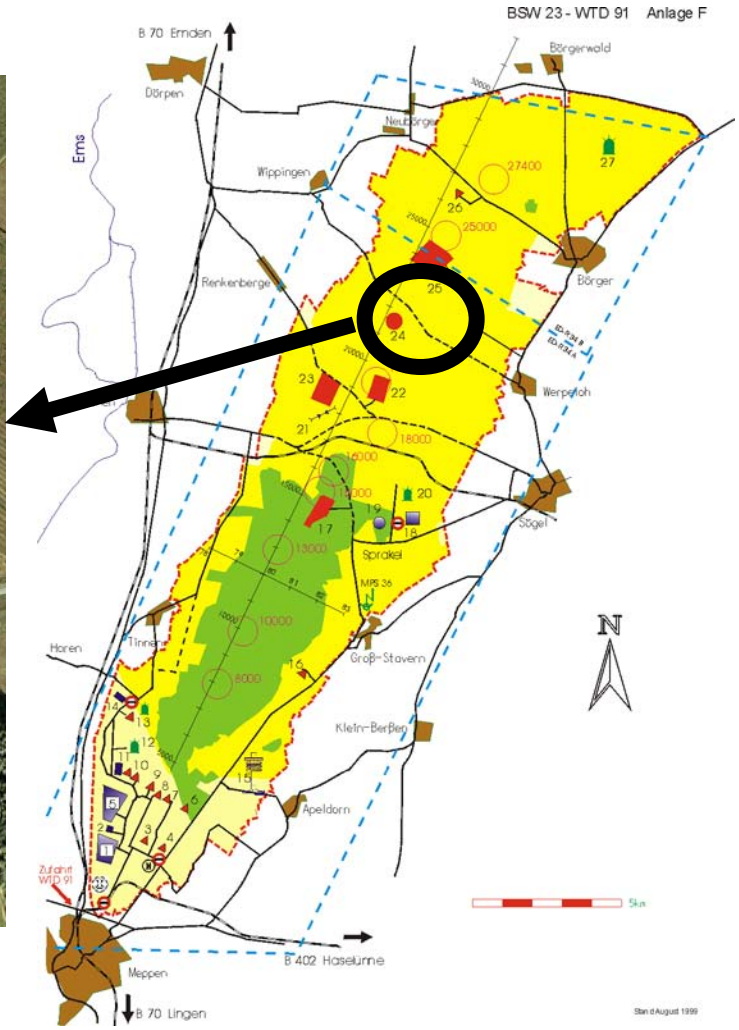
Overview on test series 2009 - 2011

No.	Test	Scale	Variant	NEQ [kg PETN]	Location	Time
1	V_1	1:2	A	25	WTD 52	2009
2	V_1R	1:2	A	25	WTD 52	2009
3	V_2	1:2	A	50	WTD 52	2009
4	V_2R	1:2	A	50	WTD 52	2009
5	V_2S	1:1	B	400	WTD 91	2009
6	V_3	1:2	A	75	WTD 91	2009
7	V_3R	1:2	A	75	WTD 91	2009
8	V_3S	1:1	B	600	WTD 91	2009
9	V_4	1:2	A	100	WTD 91	2010
10	V_4R	1:2	A	100	WTD 91	2010
11	V_5	1:2	A	125	WTD 91	2010
12	V_5R	1:2	A	125	WTD 91	2010
13	V_5S	1:2	B	125	WTD 91	2011
14	V_6	1:1	B	120mm Mörser	WTD 91	2011

-Scaled tests 1:2 → bare charges PETN
-red circle: Integrated verification tests #5 & #8 with 155mm artillery grenade in scale 1:1
-blue circle: life fire mortar tests on structure!

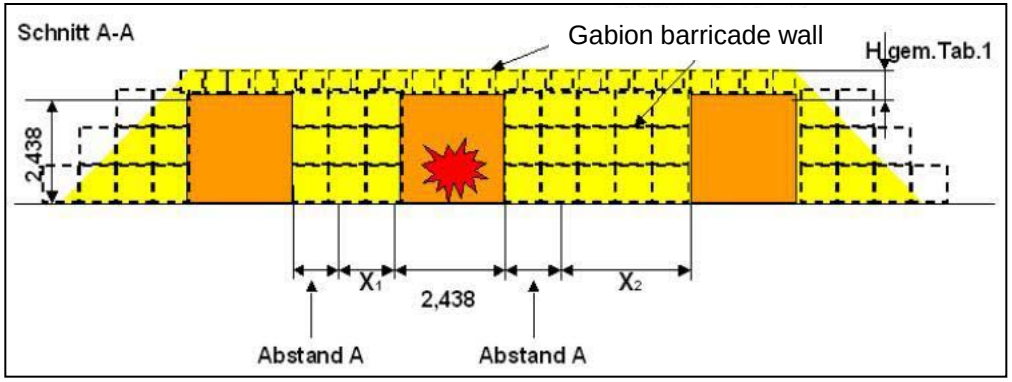
Tests at WTD 91 – scale 1:1





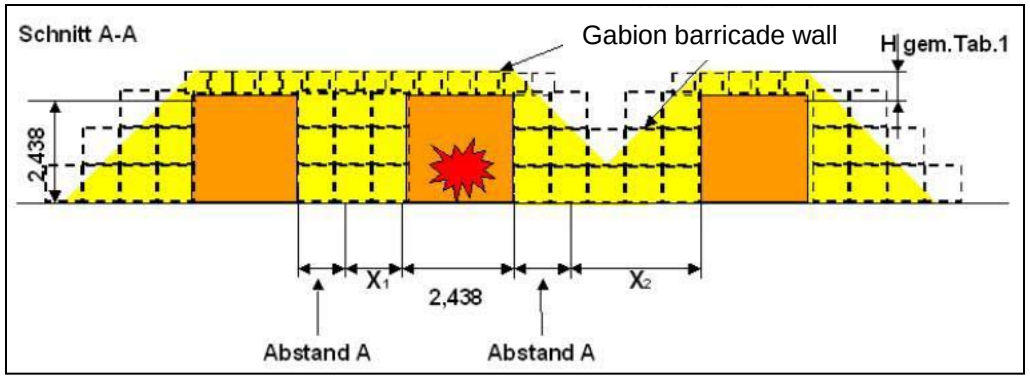
Tests at WTD 91 – scale 1:1

Variant *A*



Front view

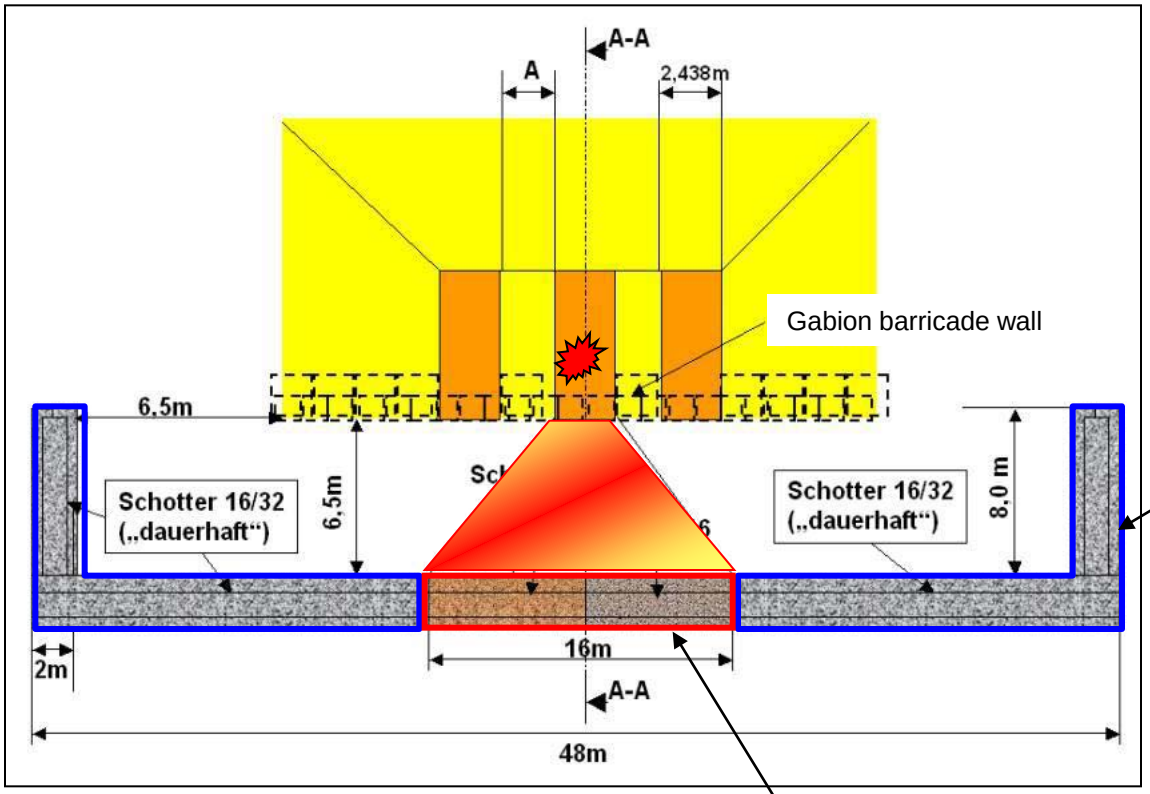
Variant *B*



Front view

Tests at WTD 91 – scale 1:1

Top View (variant ***A, B***)



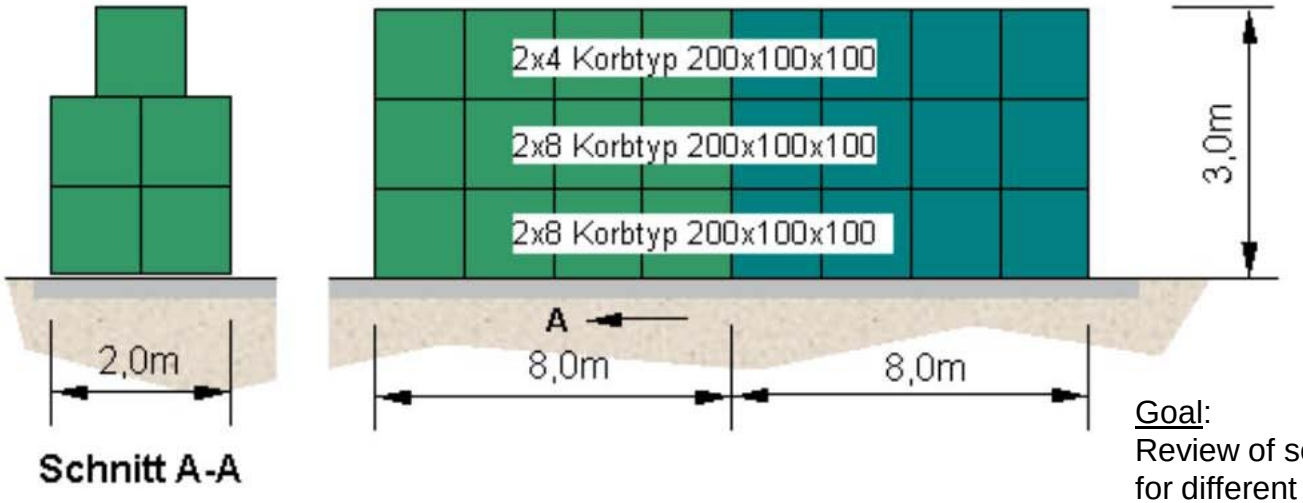
segment ‚LONG LASTING‘

segment ‚MIDDLE‘ (100% destruction expected!)

Tests at WTD 91 – scale 1:1

Design of gabion barricade wall

→ Gabion barricade wall - type 2000x3000 scale 1:1 (segment 'MIDDLE')



Goal:
Review of secondary debris effects for different infill materials

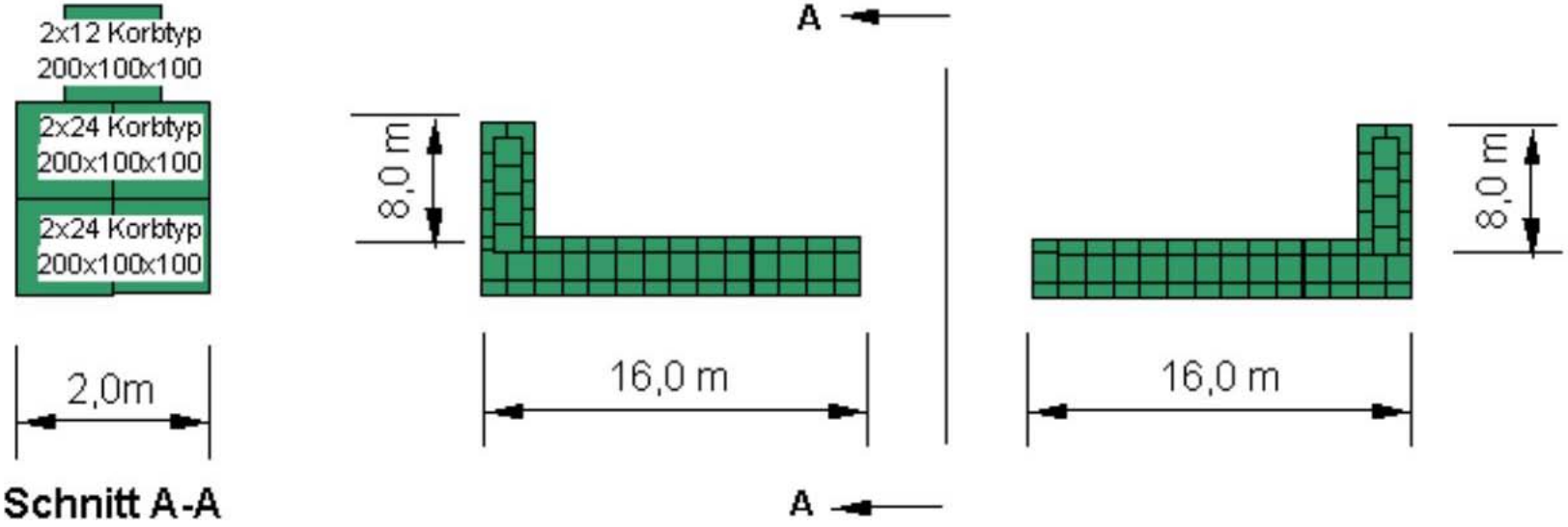
Infill material:

gravel 8/16:	**approx. 74.8 to**	installation in fill bags i.a.w. Installation Instructions
crushed rock 16/32:	**approx. 74.8 to**	installation in fill bags i.a.w. Installation Instructions

Tests at WTD 91 – scale 1:1

Design of gabion barricade wall

→ Gabion barricade wall - type 2000x3000 scale 1:1 (segment 'LONG LASTING')



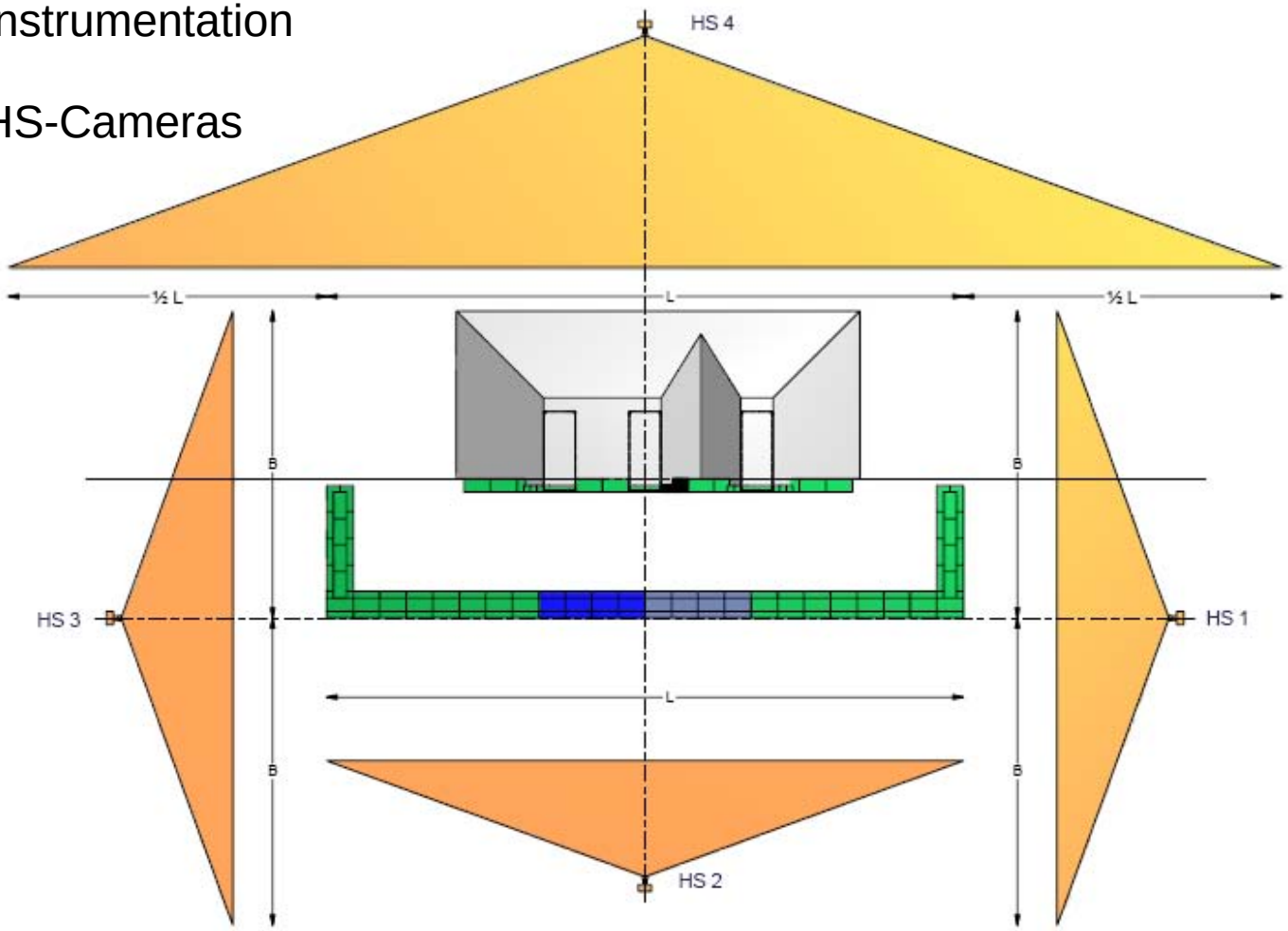
Infill material:

crushed rock 16/32: approx. 448.8 to installation in fill bags i.a.w. Installation Instructions

Tests at WTD 52/91 – scale 1:2/1:1

Instrumentation

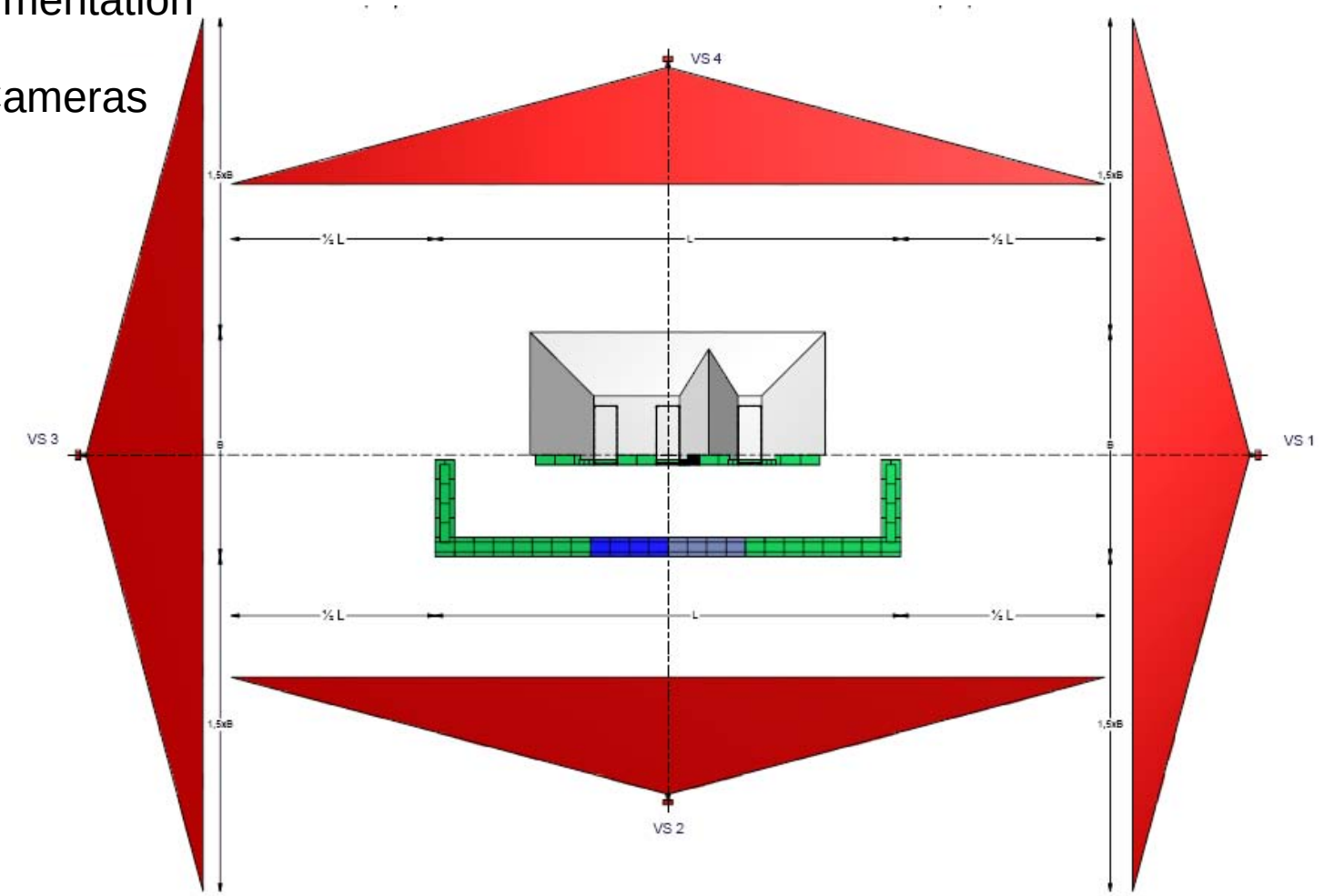
HS-Cameras



Tests at WTD 52/91 – scale 1:2/1:1

Instrumentation

VS-Cameras

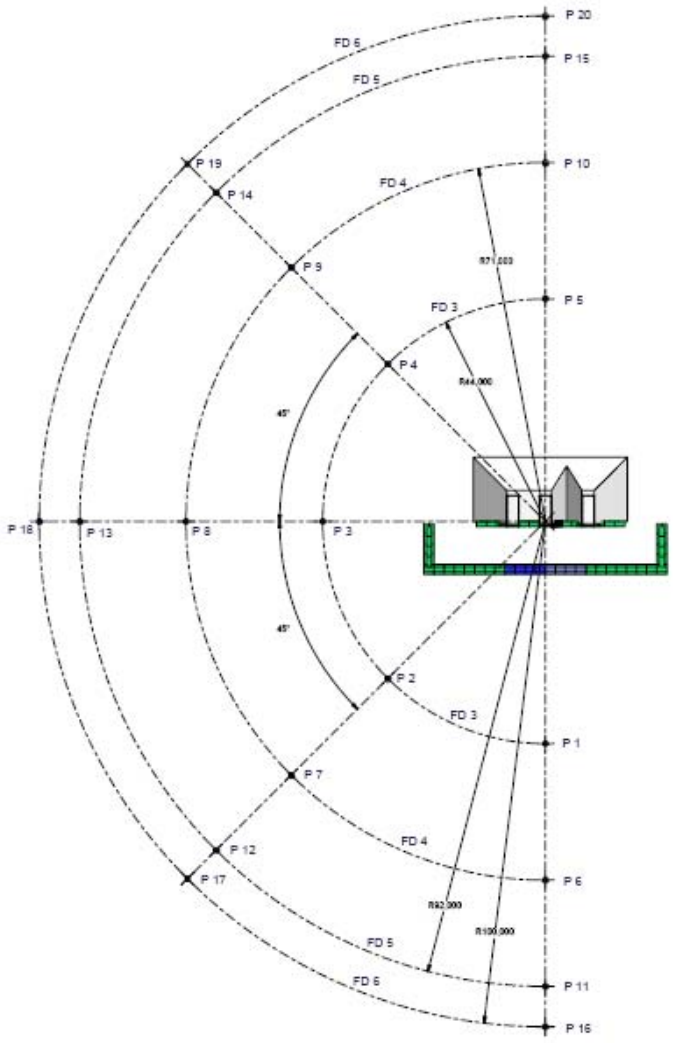


Tests at WTD 52/91 – scale 1:2/1:1

Instrumentation

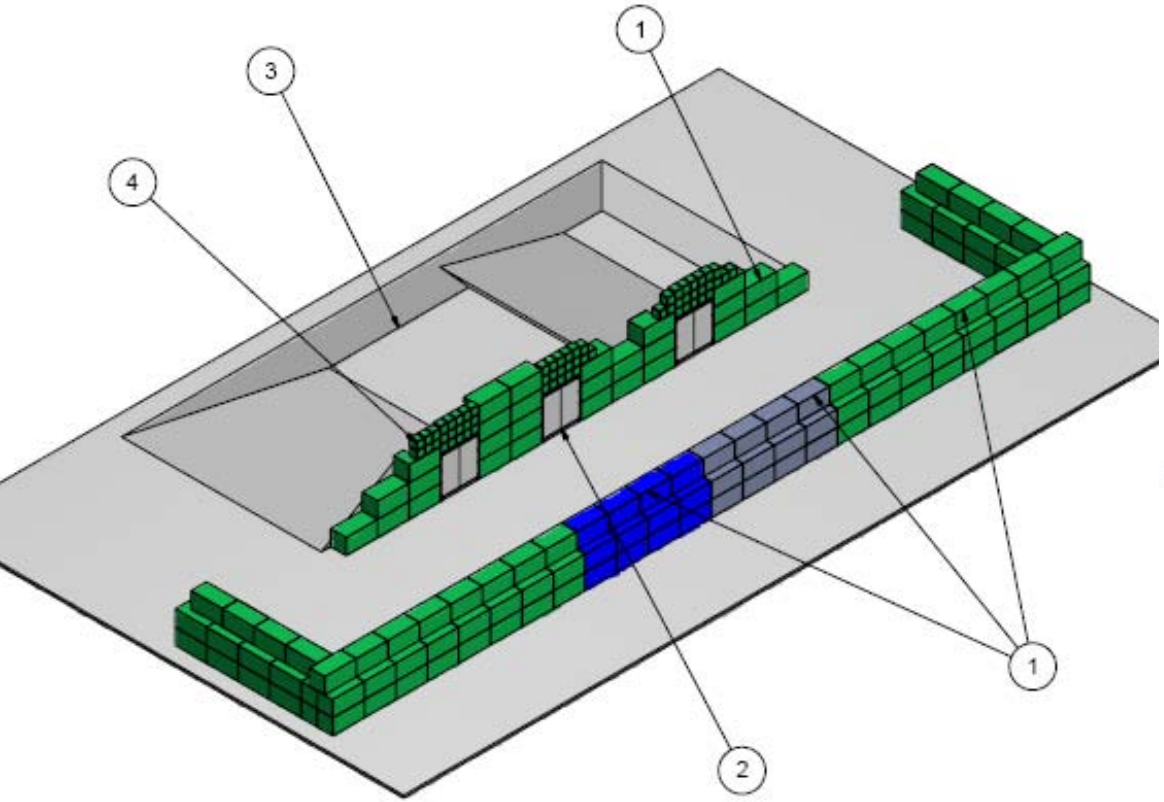
Pressure measurement

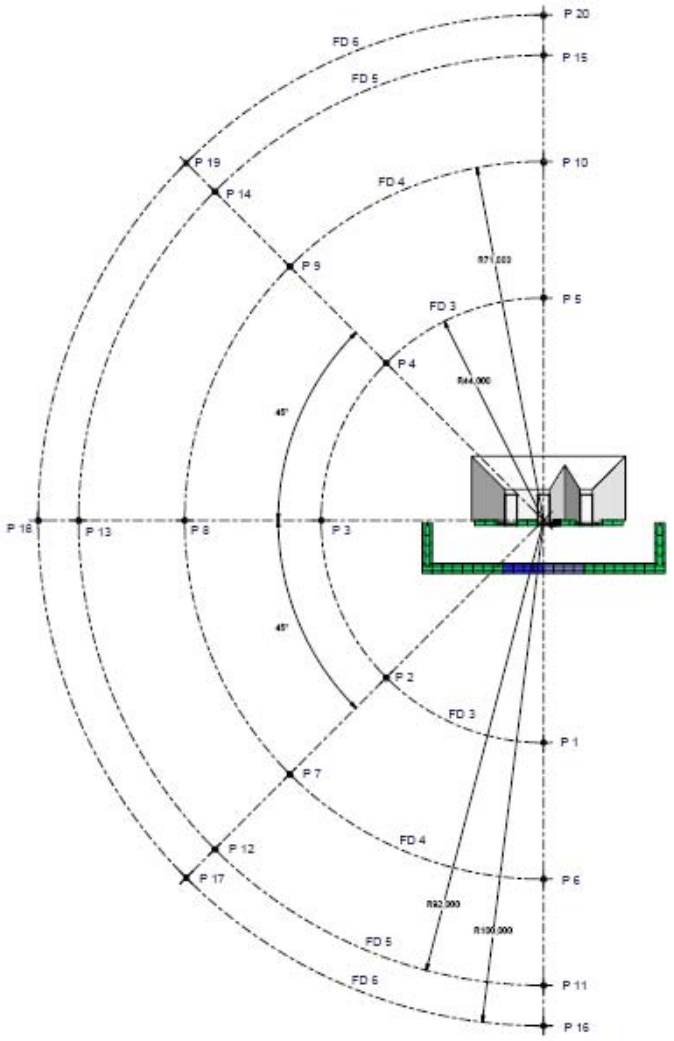
Versuch Nr.	Ladungs menge [kg]	Abstand zum Gefahrenherd [m]			
		FD3	FD4	FD5	FD6
V_1	25				
V_1R	25				
V_2	50				
V_2R	50				
V_2S	**400**	**44**	**71**	**92** (gem. AASTP 6)	**100**
V_3	**75**	**25**	**40**	**62** (gem. Weisung)	**89**
V_3R	**75**	**25**	**40**	**62** (gem. Weisung)	**89**
V_3S	600				
V_4	100				
V_4R	100				
V_5	125				
V_5R	125				
V_5S	125				
V_6	120mm Mörser	Entfällt, da Ladungsmenge zu gering			
Faktor		**6,0x** $*\sqrt[3]{M}$ **gem. AASTP5**	**9,6x** $*\sqrt[3]{M}$ **gem. Weisung**	**4,6x** $*\sqrt[3]{M}$ **gem. AASTP5** **14,8x** $*\sqrt[3]{M}$ **gem. Weisung**	**100+5,5(Q-400)** $^{1/2}$ **gem. AASTP5** **Achtung: Bezug auf 600 kg AEM im Maßstab 1:1 (entspricht 75 kg AEM in Maßstab 1:2)**



Test Conduct 2009

Example – scale 1:1 - 409.5 kg NEQ (155mm)





Example – scale 1:1 - 409.5 kg NEQ (155mm)

Example – scale 1:1 - 409.5 kg NEQ (155mm)

Earth cover - Variant B

Example – scale 1:1 - 409.5 kg NEQ (155mm)

Dummies – container to the right

Ammunition – container at the center

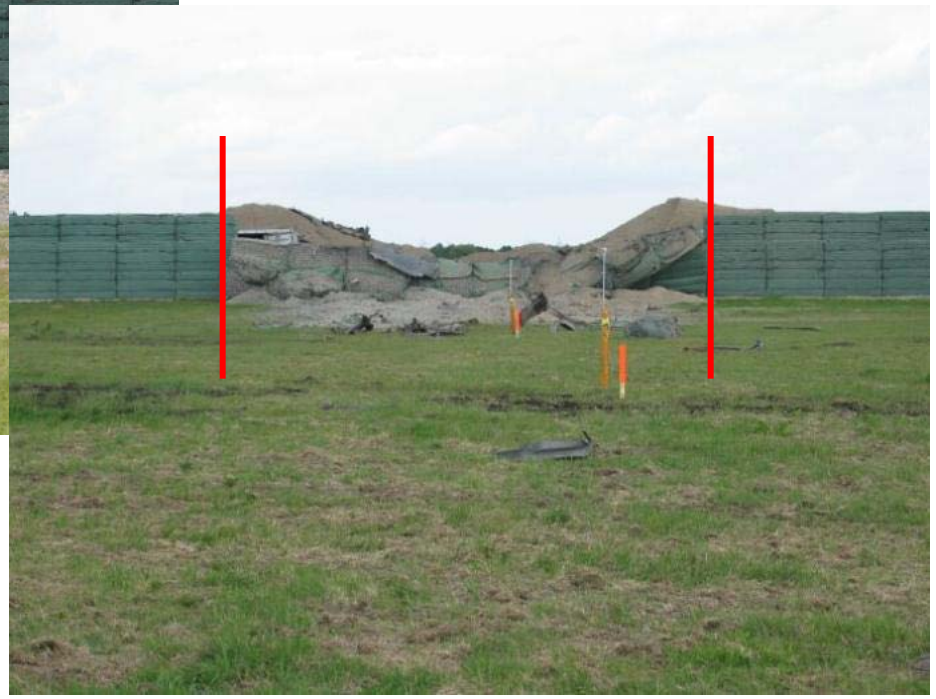
Example – scale 1:1 - 409.5 kg NEQ (155mm)

Example – scale 1:1 - 409.5 kg NEQ (155mm)

Results – Lessons Learned So Far!

Degree of damage – front face

segment ‚MIDDLE‘



Results – Lessons Learned So Far!

Degree of damage – earth cover

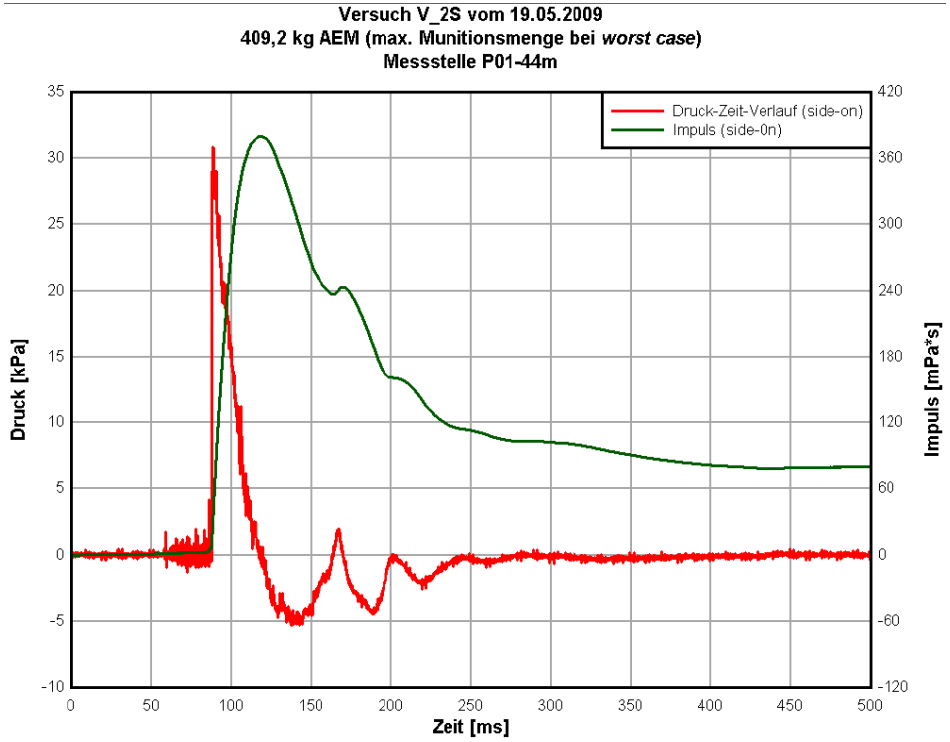
Results – Lessons Learned So Far!

Left container – internal view

Right container – internal view

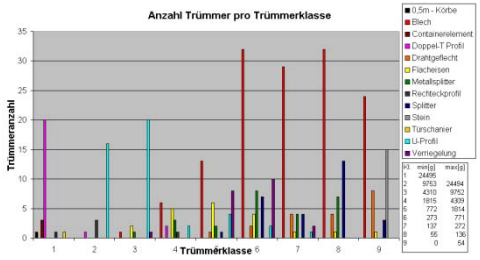
Results – Lessons Learned So Far!

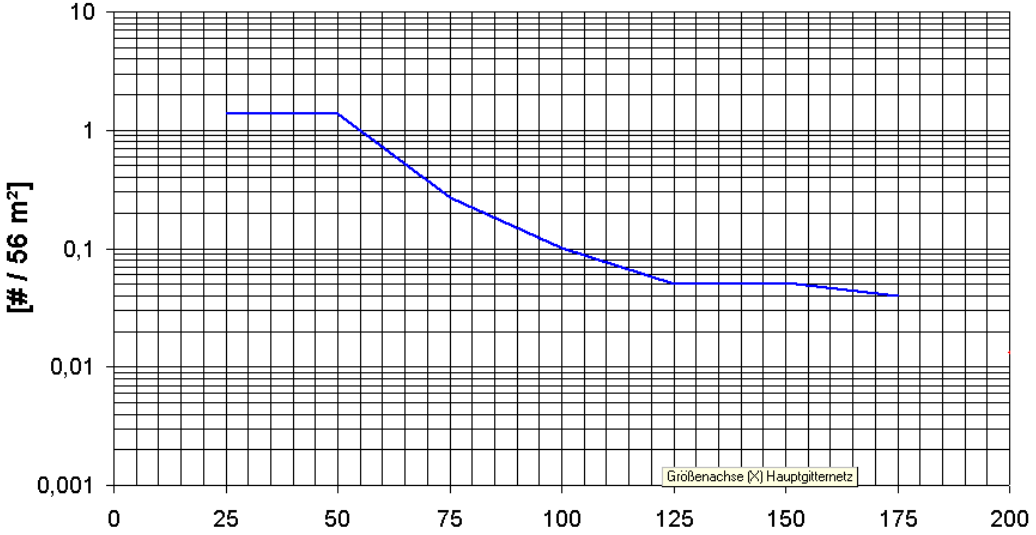
- The pressure measurements were filtered and analyzed
- A pressure-time line was drawn (in a graph) , side-on for open area
- Pulses were noted (in a graph)
- The data was entered into an Excel chart (pressure, time of impact, positive duration of pressure, pulse)
- The data was provided as an ASCII file.

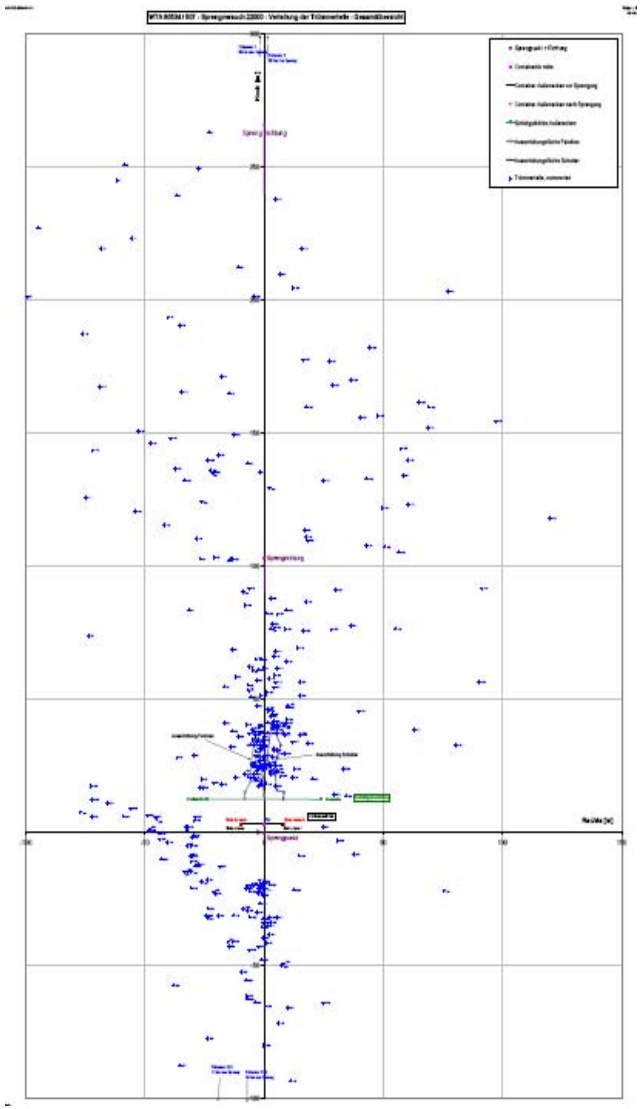


Results – Lessons Learned So Far!

- type, size, weight and shape of fragments and debris,
- their distance from the point of impact
- general photo documentation with assignment of images







Summary

No.	Test	Scale	Variant	NEQ [kg PETN]	Location	Time	
1	V_1	1:2	A	25	WTD 52	2009	2010
2	V_1R	1:2	A	25	WTD 52	2009	
3	V_2	1:2	A	50	WTD 52	2009	
4	V_2R	1:2	A	50	WTD 52	2009	
5	V_2S	1:1	B	400	WTD 91	2009	ok
6	V_3	1:2	A	75	WTD 91	2009	ok
7	V_3R	1:2	A	75	WTD 91	2009	ok
8	V_3S	1:1	B	600	WTD 91	2009	2010
9	V_4	1:2	A	100	WTD 91	2010	ok
10	V_4R	1:2	A	100	WTD 91	2010	
11	V_5	1:2	A	125	WTD 91	2010	
12	V_5R	1:2	A	125	WTD 91	2010	
13	V_5S	1:2	B	125	WTD 91	2011	
14	V_6	1:1	B	120mm Mörser	WTD 91	2011	

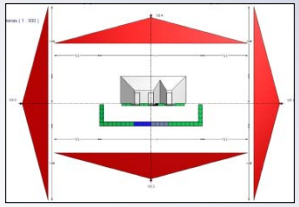
Reference Documents

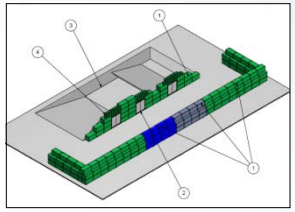
[1] **Armed Forces Office (SKA) V 6**
Military Requirement No. 238, Ammunition Storage in Earth-Covered ISO Containers
Bonn, September 2007

[2] **Steyerer M., WTD 52 – GF 210**
Time and cost schedule for “Ammunition Storage in Earth-Covered ISO Containers“
Oberjettenberg, November 2007

[3] **Steyerer M., WTD 52 – GF 210**
Test planning for “Ammunition Storage in Earth-Covered ISO Containers“
Oberjettenberg, October 2008

GF 210:





For the protection of our soldiers!